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IV

Atomic Weapons and American Policy

It is possible that in the large light of history, if indeed there is to be history, the atomic bomb will appear not very different than in the bright light of the first atomic explosion. Partly because of the mood of the time, partly because of a very clear prevision of what the technical developments would be, we had the impression that this might mark, not merely the end of a great and terrible war, but the end of such wars for mankind.

Two years later Colonel Stimson was to write in *Foreign Affairs*: "The riven atom, uncontrolled, can be only a grow-

and disunity in what we have learned to call the Free World.

In these preoccupations—one wholly negative, and one largely positive though very difficult—the atom, too, was given a simple role, and the policy followed was a fairly simple one. The role was to be one ingredient of a shield: a shield composed also in part of the great industrial power of America, and in part of the military and, even more, the political weaknesses of the Soviet Union. The rule for the atom was: "Let us keep ahead. Let us be sure that we are ahead of the enemy."

Today it would seem that, however necessary these considerations and these policies may be, they are no longer nearly sufficient. The reason for that one can see when one looks at the character of the arms race. The reason for that one can see when one compares the time-scale of atomic developments here and abroad with the probable time-scale of deep political changes in the world.

It is easy to say "Let us look at the arms race." I must tell about it without communicating anything. I must reveal its nature without revealing anything; and this I propose to do.

There are three countries embarked on this race: The United Kingdom—and of that we need to note only that it is unfortunate that so talented and hard-pressed a country, so close to us in history and tradition, should be doing all this separately from us—ourselves, and the U.S.S.R.

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it was not a question of one bomb. It would become a question of ten, and then one hundred, and then a thousand, and then ten thousand, and then maybe one hundred thousand. We knew—or, rather, we did not know, but we had very good reason to think—that it was not a question of ten thousand tons but of one hundred thousand and then a million tons, and then ten million tons and then maybe one hundred million tons.

We knew that these munitions could be adapted, not merely to a slow medium bomber operating where we had almost complete air supremacy, but to methods of delivery more modern, more flexible, harder to intercept, and more suitable for combat as it might be encountered today.

Today all of this is in train. It is my opinion that we should all know—not precisely, but quantitatively and, above all, authoritatively—where we stand in these matters; that we should all have a good idea of how rapidly the situation has changed, and of where we may stand, let us say, three, four, or five years ahead, which is about as far as one can see. I shall revert to the reasons why I think it important that we all know of these matters I cannot write of them.

What I can say is this: I have never discussed these prospects candidly with any responsible group, whether scientists or statesmen, whether citizens or officers of the government, with any group that could steadily look at the facts, that did not come away with a great sense of anxiety and somberness at what they saw. The very least we can say is that, looking ten years ahead, it is likely to be small comfort that the Soviet Union is four years behind us, and small

and in the far more tragic and difficult problem of defending our allies in Europe still less has been done. This does not promise to be an easy problem.

Atomic weapons are not just one element of an arsenal that we hope may deter the Soviet government, or just one of the means we think of for putting an end to a war, once started. It is, perhaps, almost the only military measure that anyone has in mind to prevent, let us say, a great battle in Europe from being a continuing, agonizing, large-scale Korea. It is the only military instrument which brings the Soviet Union and the United States into contact—a most uncomfortable and dangerous contact—with one another.

Atomic weapons, as everyone knows, have been incorporated in the plans for the defense of Europe. They have been developed for many tactical military uses, as in the antisubmarine campaign, the air campaign, and the ground campaign in the European theater; and these potential applications continue to ramify and multiply. Yet the Europeans are rather in ignorance of what these weapons are, how many there may be, how they will be used and what they will do. It thus needs to be remarked, as we shall need to remark again, that for Europe, the atomic weapon is both a much needed hope of effective defense and a terrible immediate peril, greater even than for this country.

These are some of the peculiarities of this arms race, marked for us by a very great rigidity of policy, and a terrifyingly rapid accumulation, probably on both sides, of a deadly munition. When we think of the terms in which we in this country tend to talk of the future, the somberness with

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ability, is a very tough fix. There are three things we need to remember, three things that are very sharp. It is perilous to forget any one of them. One is the hostility and the power of the Soviet. Another is the touch of weakness—the need for unity, the need for some stability, the need for armed strength on the part of our friends in the Free World. And the third is the increasing peril of the atom.

It is straightforward, if not easy, if we forget the last. It is easy if we forget the first. It is hard if we remember all three. But they are all there.

We need the greatest attainable freedom of action. We need strength to be able to ask whether our plans for the use of the atom are, all things considered, right or wrong. We need the freedom of action necessary—and we do not have it today—to be able to negotiate, should an opportunity for that at some future time appear.

Much will be needed to bring us this freedom of action. Some of it we cannot write about because it has not occurred to us. Some we cannot write about because it would not be proper for anything but official discussion. An example may be the question of whether, under what circumstances, in what manner, and with what purpose to communicate with the Soviet government on this and related problems.

But there are three reforms which seem so obvious, so important, so sure to be salutary that I should like to discuss them briefly. One has to do with making available to ourselves, in this tough time, the inherent resources of a country like ours and a government like ours. These resources are not available today. The second has to do with making avail-

one of them a most distinguished scientist, who headed one of the great projects of the Manhattan District during the war, and one of them a brilliant officer, who was in over-all charge of the Manhattan District. These two men are not now employed by any agency of the government concerned with these questions; therefore they did not have access to the evidence. Thus their advice is unavailing, their public counsel wrong.

A second example may illustrate further. A high officer of the Air Defense Command said—and this only a few months ago, in a most serious discussion of measures for the continental defense of the United States—that it was our policy to attempt to protect our striking force, but not really our policy to attempt to protect this country, for that is so big a job that it would interfere with our retaliatory capabilities. Such follies can occur only when even the men who know the facts can find no one to talk to about them, when the facts are too secret for discussion, and thus for thought.

The political vitality of our country largely derives from two sources. One is the interplay, the conflict of opinion and debate, in many diverse and complex agencies, legislative and executive, which contribute to the making of policy. The other is a public opinion which is based on confidence that it knows the truth.

Today public opinion cannot exist in this field. No responsible person will hazard an opinion in a field where he believes that there is somebody else who knows the truth, and where he believes that he does not know it. It is true that there are and always will be, as long as we live in danger of

enemy must now know: To describe in rough but authoritative and quantitative terms what the atomic armaments race is. It is not enough to say, as our government so often has, that we have made "substantial progress." When the American people are responsibly informed, we may not have solved, but we shall have a new freedom to face, some of the tough problems that are before us.

There is also need for candor in our dealings at least with our major allies. The Japanese are exposed to atomic bombardment; and it may be very hard to develop adequate countermeasures. Space, that happy asset of the United States, is not an asset for Japan. It is not an asset for France. It is not an asset for England. There are in existence methods of delivery of atomic weapons which present an intractable problem of interception, and which are relevant for the small distances that characterize Europe. It will be some time at least before they are relevant for intercontinental delivery. These countries will one day feel a terrible pinch, when the U.S.S.R. chooses to remind them of what it can do, and do very easily—not without suffering, but in a way that the Europeans themselves can little deter or deflect.

There have been arguments for technical collaboration with the United Kingdom and Canada; these have often appeared persuasive. There have been arguments for military collaboration with the NATO governments, and with the responsible commanders involved; General Bradley and General Collins both have spoken of this need, partly in order to explain to our allies that an atomic bomb will not do all things—that it has certain capabilities but it is not the whole

war, secrets that it is important to keep secret, at least for an appropriate period, if not for all time; some of these, and important ones, are in the field of atomic energy. But knowledge of the characteristics and probable effects of our atomic weapons, of—in rough terms—the numbers available, and of the changes that are likely to occur within the next years, this is not among the things to be kept secret. Nor is our general estimate of where the enemy stands.

Many arguments have been advanced against making public this basic information. Some of these arguments had merit in times past. One is that we might be giving vital information to the enemy. My own view is that the enemy has this information. It is available to anyone who will trouble to make an intelligence analysis of what has been published. Private citizens do not do this; but we must expect that the enemy does. It is largely available by other means as well. It is also my view that it is good for the peace of the world if the enemy knows these basic facts—very good indeed, and very dangerous if he does not.

There is another source of worry—that public knowledge of the situation might induce in this country a mood of despair, or a too ready acceptance of what is lightheartedly called preventive war. I believe that until we have looked this tiger in the eye, we shall be in the worst of all possible dangers, which is that we may back into him. More generally, I do not think a country like ours can in any real sense survive if we are afraid of our people.

As a first step, but a great one, we need the courage and the wisdom to make public at least what, in all reason, the

enemy must now know: To describe in rough but authoritative and quantitative terms what the atomic armaments race is. It is not enough to say, as our government so often has, that we have made "substantial progress." When the American people are responsibly informed, we may not have solved, but we shall have a new freedom to face, some of the tough problems that are before us.

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answer. This is surely a precondition for effective planning, and for the successful defense of Europe.

Yet there are much more general reasons. We and our allies are in this long struggle together. What we do will affect the destiny of Europe; what is done there will affect ours; and we cannot operate wisely if a large half of the problem we have in common is not discussed in common. This does not mean that we should tie our hands. It means that we should inform and consult. This could make a healthy and perhaps very great change in our relations with Europe.

It is not clear that the situation even in the Far East would be wholly unaffected. It is troublesome to read that a principal reason that we should not use atomic weapons in Korea is that our allies would not like it. We need not argue here either that it is right or that it is wrong to use them there. In either case, our decisions should rest on far firmer ground than that other governments, who know less than we about the matter, should hold a different view than ours. It would be proper that the Japanese and the British and the many other governments immediately involved have a notion of what the issues really are.

Once, clearly, the problem of proper candor at home is faced—the problem of a more reasonable behavior toward our own people and our representatives and officials with regard to the atom—then the problem of dealing with our allies will be less troublesome. For it is pretty much the same information, the same rough set of facts, that both our people and our allies need to have and to understand.

The third point may seem even more obvious. I do not be-

lieve—though of course we cannot today be certain—that we can take measures for the defense of our people, our lives, our institutions, our cities, which will in any real sense be a permanent solution to the problem of the atom. But that is no reason for not doing a little better than we are now doing.

The current view, as is well known, is not very optimistic. Not long ago General Vandenberg estimated that we might, with luck, intercept twenty or thirty per cent of an enemy attack. That is not very reassuring, when one looks at numbers and casualties, and what it takes to destroy the heart and life of our country. For some months now, a highly qualified panel, under the chairmanship of Dr. Mervin Kelly, appointed by Secretary Lovett and reporting now to Secretary Wilson, has studied the complex technical problems of continental defense. There are many technical developments that have not yet been applied in this field, and that could well be helpful. They are natural but substantial developments in munitions, in aircraft and in missiles, and in procedures for obtaining and analyzing information. Above all, there is the challenging problem of the effective use of space; there is space between the Soviet Union and the United States. This panel, it would appear, has been oppressed and troubled by the same over-all oppression which any group always finds, when it touches seriously any part of the problem of the atom. Yet there is no doubt that it will recommend sensible ways in which we can proceed to try to defend our lives and our country.

Such measures will inevitably have many diverse meanings. They will mean, first of all, some delay in the im-

ey have not, in any deep sense, been generally understood. We need to be clear that there will not be many great atomic wars for us, nor for our institutions. It is important that there not be one. We need to liberate our own great resources, to shape our destiny.

minence of the threat. They will mean a disincentive—a defensive deterrent—to the Soviet Union. They will mean that the time when the Soviet Union can be confident of destroying the productive power of America will be somewhat further off—very much further off than if we did nothing. They will mean, even to our allies, who are much more exposed and probably cannot be well defended, that the continued existence of a real and strong America will be a solid certainty which should discourage the outbreak of war.

A more effective defense could even be of great relevance, should the time come for serious discussion of the regulation of armaments. There will have been by then a vast accumulation of materials for atomic weapons, and a troublesome margin of uncertainty with regard to its accounting—very troublesome indeed if we still live with vestiges of the suspicion, the hostility and secretiveness of the world of today. This will call for a very broad and robust regulation of armaments, in which existing forces and weapons are of a wholly different order than those required for the destruction of one great nation by another, in which steps of evasion will be either far too vast to conceal or far too small to have, in view of then existing measures of defense, a decisive strategic effect. Defense and regulation may thus be necessary complements. And here, too, all that we do effectively to contribute to our own immunity will be helpful in giving us some measure of an increased freedom of action.

These are three paths that we may take. None of them is a wholly new suggestion. They have, over the long years, been discussed; but they have not been acted on. In my opinion

they have not, in any deep sense, been generally understood. We need to be clear that there will not be many great atomic wars for us, nor for our institutions. It is important that there not be one. We need to liberate our own great resources, to shape our destiny.

V

Physics in the Contemporary World

If I have even in the title of this talk sought to restrict its theme, that does not imply an overestimate of physics among the sciences, nor a too great myopia for these contemporary days. It is rather that I must take my starting point in the science in which I have lived and worked, and a time through which my colleagues and I are living.

Nevertheless, I shall be talking tonight about things which are quite general for the relations between science and civilization. For it would seem that in the ways of science, its practice, the peculiarities of its discipline and universality, there

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from experience, for relationships of this kind; and one of the most apt is the exclusive relationship between the practicing of an art and the description of that practice. Both are a part of civilized life. But an analysis of what we do and the doing of it—these are hard to bed in the same bed.

As it did on everything else, the last world war had a great and at least a temporarily disastrous effect on the prosecution of pure science. The demands of military technology in this country and in Britain, the equally overriding demands of the Resistance in much of Europe, distracted the physicists from their normal occupations, as they distracted most other men.

We in this country, who take our wars rather spastically, perhaps witnessed a more total cessation of true professional activity in the field of physics, even in its training, than did any other people. For in all the doings of war we, as a country, have been a little like the young physicist who went to Washington to work for the National Defense Research Committee in 1940. There he met his first Civil Service questionnaire and came to the questions on drinking: "Never," "occasionally," "habitually," "to excess." He checked both "occasionally" and to "to excess." So, in the past, we have taken war.

All over the world, whether because of the closing of universities, or the distractions of scientists called in one way or another to serve their countries, or because of devastation and terror and attrition, there was a great gap in physical science. It has been an exciting and an inspiring sight to watch the recovery—a recovery testifying to extraordinary

in the findings about these particles. We are meeting new es for which we are not prepared. We are learning how orly we had identified the properties even of our old iends among them. We are seeing what a challenging job e ordering of this experience is likely to be, and what a strange world we must enter to find that order.

In penetrating into this world perhaps our sharpest tool in the past has been the observation of the phenomena of the cosmic rays in interaction with matter. But the next years will see an important methodological improvement, when the great program of ultra-high-energy accelerators begins to get under way. This program is itself one of the expensive parts of physics. It has been greatly subsidized by the government, primarily through the Atomic Energy Commission and the Office of Naval Research. It is a superlative example, of which one could find so many, of the repayment that technology makes to basic science, in providing means whereby our physical experience can be extended and enriched.

Another progress is the definement of our knowledge of the behavior of electrons within atomic systems, a refinement which on the one hand is based on the microwave techniques, to the developments of which the Radiation Laboratory of the Massachusetts Institute of Technology made unique contributions, and which on the other hand has provided a newly vigorous criterion for the adequacy of our knowledge of the interactions of radiation and matter. Thus we are beginning to see in this field at least a partial resolu-

tion, and I am myself inclined to think rather more than that, of the paradoxes that have plagued the professional physical theorists for two decades.

A third advance in atomic physics is in the increasing understanding of those forces which give to atomic nuclei their great stability, and to their transmutations their great violence. It is the prevailing view that a true understanding of these forces may well not be separable from the ordering of our experience with regard to elementary particles, and that it may also turn on an extension to new fields of recent advances in electrodynamics.

However this may be, all of us who are physicists by profession know that we are embarked on another great adventure of exploration and understanding, and count ourselves happy for that.

In how far is this an account of physics in the United States only? In how far does it apply to other parts of the world, more seriously ravaged and more deeply disturbed by the last war? That question may have a somewhat complex answer, to the varied elements of which one may pay respectful attention.

In much of Europe and in Japan, that part of physics which does not rest on the availability of elaborate and radical new equipment is enjoying a recovery comparable to our own. The traditional close associations of workers in various countries makes it just as difficult now to disentangle the contributions by nationality as it was in the past. But there can be little doubt that it is very much harder for a physicist in France, for instance, or the Low Countries, and very much

more nearly impossible for him in Japan, to build a giant accelerator than it is for the workers in this country.

Yet in those areas of the world where science has not merely been disturbed or arrested by war and by terror, but where terror and its official philosophy have, in a deep sense, corrupted its very foundations, even the traditional fraternity of scientists has not proved adequate protection against decay. It may not be clear to us in what way and to what extent the spirit of scientific inquiry may come to apply to matters not yet and perhaps never to be part of the domain of science; but that it does apply, there is one very brutal indication. Tyranny, when it gets to be absolute, or when it tends so to become, finds it impossible to continue to live with science.

Even in the good ways of contemporary physics, we are reluctantly made aware of our dependence on things which lie outside our science. The experience of the war, for those who were called upon to serve the survival of their civilization through the Resistance, and for those who contributed more remotely, if far more decisively, by the development of new instruments and weapons of war, has left us with a legacy of concern. In these troubled times it is not likely that we shall be free of it altogether. Nor perhaps is it right that we should be.

Nowhere is this troubled sense of responsibility more acute, and surely nowhere has it been more prolix, than among those who participated in the development of atomic energy for military purposes. I should think that most historians would agree that other technical developments, no-

ho perhaps would have liked, had the world let him, to have ought of his science as something independent of worldly icissitudes. Hilbert had a colleague, an equally eminent athematician, Felix Klein, who was certainly aware, if not f the dependence of science generally on society, at least of he dependence of mathematics on the physical sciences hich nourish it and give it application. Klein used to take ome of his students to meet once a year with the engineers f the Technical High School in Hanover. One year he was ill and asked Hilbert to go in his stead, and urged him, in the little talk that he would give, to try to refute the then prevalent notion that there was a basic hostility between science and technology. Hilbert promised to do so; but when the time came a magnificent absent-mindedness led him instead to speak his own mind: "One hears a good deal nowadays of the hostility between science and technology. I don't think that is true, gentlemen. I am quite sure that it isn't true, gentlemen. It almost certainly isn't true. It really can't be true. *Sie haben ja gar nichts mit einander zu tun.* They have nothing whatever to do with one another." Today the wars and the troubled times deny us the luxury of such absent-mindedness.

The great testimony of history shows how often in fact the development of science has emerged in response to technological and even economic needs, and how in the economy of social effort, science, even of the most abstract and recondite kind, pays for itself again and again in providing the basis for radically new technological developments. In fact, most people—when they think of science as a good thing,

tably radar, played a more decisive part in determining the outcome of this last war. But I doubt whether that participation would have of itself created the deep trouble and moral concern which so many of us who were physicists have felt, have voiced, and have tried to get over feeling. It is not hard to understand why this should be so. The physics which played the decisive part in the development of the atomic bomb came straight out of war laboratories and our journals.

Despite the vision and the far-seeing wisdom of our wartime heads of state, the physicists felt a peculiarly intimate responsibility for suggesting, for supporting, and in the end, in large measure, for achieving the realization of atomic weapons. Nor can we forget that these weapons, as they were in fact used, dramatized so mercilessly the inhumanity and evil of modern war. In some sort of crude sense which no vulgarity, no humor, no overstatement can quite extinguish, the physicists have known sin; and this is a knowledge which they cannot lose.

Probably in giving expression to such feelings of concern most of us have belabored the influence of science on society through the medium of technology. This is natural, since the developments of the war years were almost exclusively technological, and since the participation of academic scientists forced to be deeply aware of an activity of whose existence they had always known but which had been often remote from them.

When I was a student at Göttingen twenty years ago, there was a story current about the great mathematician Hilbert,

who perhaps would have liked, had the world let him, to have thought of his science as something independent of worldly vicissitudes. Hilbert had a colleague, an equally eminent mathematician, Felix Klein, who was certainly aware, if not of the dependence of science generally on society, at least of the dependence of mathematics on the physical sciences which nourish it and give it application. Klein used to take some of his students to meet once a year with the engineers of the Technical High School in Hanover. One year he was ill and asked Hilbert to go in his stead, and urged him, in the little talk that he would give, to try to refute the then prevalent notion that there was a basic hostility between science and technology. Hilbert promised to do so; but when the time came a magnificent absent-mindedness led him instead to speak his own mind: "One hears a good deal nowadays of the hostility between science and technology. I don't think that is true, gentlemen. I am quite sure that it isn't true, gentlemen. It almost certainly isn't true. It really can't be true. *Sie haben ja gar nichts mit einander zu tun.* They have nothing whatever to do with one another." Today the wars and the troubled times deny us the luxury of such absent-mindedness.

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when they think of it as worthy of encouragement, when they are willing to see their governments spend substance upon it, when they greatly do honor to men who in science have attained some eminence—have in mind that the conditions of their life have been altered just by such technology, of which they may be reluctant to be deprived.

The debt of science to technology is just as great. Even the most abstract researches owe their very existence to things that have taken place quite outside of science, and with the primary purpose of altering and improving the conditions of man's life. As long as there is a healthy physics, this mutual fructification will surely continue. Out of its work there will come in the future, as so often in the past, and with an apparently chaotic unpredictability, things which will improve man's health, ease his labor, and divert and edify him. There will come things which, properly handled, will shorten his working day and take away the most burdensome part of his effort, which will enable him to communicate, to travel, and to have a wider choice both in the general question of how he is to spend his life and in the specific question of how he is to spend an hour of his leisure. There is no need to belabor this point, nor its obverse—that out of science there will come, as there has in this last war, a host of instruments of destruction which will facilitate that labor, even as they have facilitated all others.

But no scientist, no matter how aware he may be of these fruits of his science, cultivates his work, or refrains from it, because of arguments such as these. No scientist can hope to evaluate what his studies, his researches, his experiments

may in the end produce for his fellow men, except in one respect—if they are sound, they will produce knowledge. And this deep complementarity between what may be conceived to be the social justification of science and what is for the individual his compelling motive in its pursuit makes us look for other answers to the question of the relation of science to society.

One of these is that the scientist should assume responsibility for the fruits of his work. I would not argue against this, but it must be clear to all of us how very modest such assumption of responsibility can be, how very ineffective it has been in the past, how necessarily ineffective it will surely be in the future. In fact, it appears little more than exhortation to the man of learning to be properly uncomfortable, and, in the worst instances, is used as a sort of screen to justify the most casual, unscholarly and, in the last analysis, corrupt intrusion of scientists into other realms of which they have neither experience nor knowledge, nor the patience to obtain them.

The true responsibility of a scientist, as we all know, is to the integrity and vigor of his science. And because most scientists, like all men of learning, tend in part also to be teachers, they have a responsibility for the communication of the truths they have found. This is at least a collective if not an individual responsibility. That we should see in this any insurance that the fruits of science will be used for man's benefit, or denied to man when they make for his distress or destruction, would be a tragic naïveté.

There is another side of the coin. This is the question of

to the natural corruptions of their time, it is doing a great deal, and all that we may rightly ask of it. For if Plato believed that in the study of geometry, a man might prepare himself for wisdom and responsibility in the world of men, it was precisely because he thought so hopefully that the understanding of men could be patterned after the understanding of geometry. If we believe that today, it is in a much more recondite sense, and a much more cautious one.

Where, then, is the point? For one thing, it is to describe some of the features of the professional life of the scientist, which make of it one of the great phenomena of the contemporary world. Here again I would like to speak of physics; but I have enough friends in the other sciences to know how close their experience is to ours. And I know too that despite profound differences in method and technique, differences which surely are an appropriate reflection of the difference in the areas of the world under study, what I would say of physics will seem familiar to workers in other disparate fields, such as mathematics or biology.

What are some of these points? There is, in the first instance, a total lack of authoritarianism, which is hard to comprehend or to admit unless one has lived with it. This is accomplished by one of the most exacting of intellectual disciplines. In physics the worker learns the possibility of error very early. He learns that there are ways to correct his mistakes; he learns the futility of trying to conceal them. For it is not a field in which error awaits death and subsequent generations for verdict—the next issue of the journals will take care of it. The refinement of techniques for the prompt

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discovery of error serves as well as any other as a hallmark of what we mean by science.

In any case, it is an area of collective effort in which there is a clear and well-defined community whose canons of taste and order simplify the life of the practitioner. It is a field in which the technique of experiment has given an almost perfect harmony to the balance between thought and action. In it we learn, so frequently that we could almost become accustomed to it, how vast is the novelty of the world, and how much even the physical world transcends in delicacy and in balance the limits of man's prior imaginings. We learn that views may be useful and inspiriting although they are not complete. We come to have a great caution in all assertions of totality, of finality or absoluteness.

In this field quite ordinary men, using what are in the last analysis only the tools which are generally available in our society, manage to unfold for themselves and all others who wish to learn, the rich story of one aspect of the physical world, and of man's experience. We learn to throw away those instruments of action and those modes of description which are not appropriate to the reality we are trying to discern, and in this most painful discipline, find ourselves modest before the world.

The question which is so much in our mind is whether a comparable experience, a comparable discipline, a comparable community of interest, can in any way be available to mankind at large. I suppose that all the professional scientists together number some one one-hundredth of a per cent of the men of the world—even this will define rather gen-

erously what we mean by scientists. Scientists as professionals are, I suppose, rather sure to constitute a small part of our people.

Clearly, if we raise at all this question that I have raised, it must be in the hope that there are other areas of human experience that may be discovered or invented or cultivated, and to which the qualities which distinguish scentific life may be congenial and appropriate. It is natural that serious scientists, knowing of their own experience something of the quality of their profession, should just today be concerned about its possible extension. For it is a time when the destruction and the evil of the last quarter century make men everywhere eager to seek all that can contribute to their intellectual life, some of the order and freedom and purpose which we conceive the great days of the past to have. Of all intellectual activity, science alone has flourished in the last centuries, science alone has turned out to have the kind of universality among men which the times require. I shall be disputed in this; but it is near to truth.

If one looks at past history, one may derive some encouragement for the hope that science, as one of the forms of reason, will nourish all of its forms. One may note how integral the love and cultivation of science were with the whole awakening of the human spirit which characterized the Renaissance. Or one may look at the late seventeenth and eighteenth centuries in France and England and see what pleasure and what stimulation the men of that time derived from the growth of physics, astronomy and mathematics.

What perhaps characterizes these periods of the past,

which we must be careful not to make more heroic because of their remoteness, was that there were many men who were able to combine in their own lives the activities of a scientist with activities of art and learning and politics, and were able to carry over from the one into the others this combination of courage and modesty which is the lesson that science always tries to teach to anyone who practices it.

And here we come to a point we touched earlier. It is very different to hear the results of science, as they may be descriptively or even analytically taught in a class or in a book or in the popular talk of the time; it is very different to hear these and to participate even in a modest way in the actual attainment of new knowledge. For it is just characteristic of all work in scientific fields that there is no authority to whom to refer, no one to give canon, no one to blame if the picture does not make sense.

Clearly these circumstances pose a question of great difficulty in the field of education. For if there is any truth in the views that I have outlined, there is all the difference in the world between hearing about science or its results and sharing in the experience of the scientist himself and of that of the scientific community. We all know that an awareness of this, and an awareness of the value of science as method, rather than science as doctrine, underlies the practices of teaching to scientist and layman alike. For surely the whole notion of incorporating a laboratory in a high school or college is a deference to the belief that not only what the scientist finds but how he finds it is worth learning and teaching and worth living through.

Yet there is something fake about all this. No one who has had to do with elementary instruction can have escaped a sense of artificiality in the way in which students are led, by the calculations of their instructors, to follow paths which will tell them something about the physical world. Precisely that groping for what is the appropriate experiment, what are the appropriate terms in which to view subtle or complex phenomena, which are the substance of scientific effort, almost inevitably are distilled out of it by the natural patterns of pedagogy. The teaching of science to laymen is not wholly a loss; and here perhaps physics is an atypically bad example. But surely they are rare men who, entering upon a life in which science plays no direct part, remember from their early courses in physics what science is like or what it is good for. The teaching of science is at its best when it is most like an apprenticeship.

President Conant, in his sensitive and thoughtful book *On Understanding Science*, has spoken at length of these matters. He is aware of how false it is to separate scientific theory from the groping, fumbling, tentative efforts which lead to it. He is aware that it is science as method and not as doctrine which we should try to teach. His basic suggestion is that we attempt to find, in the history of our sciences, stories which can be re-created in the instruction and experiment of the student and which thus can enable him to see at firsthand how error may give way to less error, confusion to less confusion, and bewilderment to insight.

The problem that President Conant has here presented is indeed a deep one. Yet he would be quite willing, I think,

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differs in a most profound way from the reality. In fact, it would seem that only those who had some firsthand experience in the acquisition of new knowledge in some disciplined field would be able truly to appreciate how great the science of the past has been, and would be able to measure those giant accomplishments against their own efforts to penetrate a few millimeters farther into darkness that surrounds them.

Thus it would seem at least doubtful that the spiritual fruits of science could be made generally available, either by the communication of its results, or by the study of its history, or by the necessarily somewhat artificial re-enactment of its procedures. Rather it would seem that there are general features of the scientists' work the direct experience of which in any context could contribute more to this end. All of us, I suppose, would list such features and find it hard to define the words which we found it necessary to use in our lists. But on a few, a common experience may enable us to talk in concert.

In the first instance the work of science is co-operative; a scientist takes his colleagues as judges, competitors and collaborators. That does not mean, of course, that he loves his colleagues; but it gives him a way of living with them which would be not without its use in the contemporary world. The work of science is discipline in that its essential inventiveness is most of all dedicated to means for promptly revealing error. One may think of the rigors of mathematics and the virtuosity of physical experiment as two examples. Science is disciplined in its rejection of questions that cannot be answered and in its grinding pursuit of methods for answering

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locus of thinking is known to us. Nor have we found good avenues for extending or deepening our experience that bears upon this problem. In short, almost all the preconditions of scientific activity are missing, and in this case, at least, one may have a melancholy certainty that man's inventiveness will not rapidly provide them. All that we have from science in facing such great questions is a memory of our professional life, which makes us somewhat skeptical of other people's assertions, somewhat critical of enthusiasms so difficult to define and to control.

Yet the past century has seen many valid and inspiriting examples for the extension of science to new domains. As even in the case of physics, the initial steps are always controversial; probably we should not as a group be unanimous in saying which of these extensions were hopeful, and which not, for the science of the future. But one feature which I cannot fail to regard as sound—particularly in the fields of biology and psychology—is that they provide an appropriate means of correlating understanding and action, and involve new experimental procedures in terms of which a new conceptual apparatus can be defined; above all, they give us means of detecting error. In fact, one of the features which must arouse our suspicion of the dogmas some of Freud's followers have built up on the initial brilliant works of Freud is the tendency toward a self-sealing system, a system, that is, which has a way of almost automatically discounting evidence which might bear adversely on the doctrine. The whole point of science is to do just the opposite: to invite the detection of error and to welcome it. Some of you may

VI

The Encouragement of Science

We are here tonight to honor you and to celebrate the high promise of your future as scientists. We are happy to be with you. We think of that future with respect and curiosity. We think of the discoveries which you will make. We think of the questions to which we today have no answer and to which you will come to know an answer. Even more, we think of the answers that we have today and of the new questions that you will put to those answers. We think of how altered and how deepened our knowledge of the world will be before you are through with it. My first wish to you

lished the means by which people in remote parts of the earth can communicate with each other, can get to know each other, and can learn to work together. They have put at the disposal of everyone the resources of physical power, of ease and of knowledge that were in the past reserved for the few.

Not all the changes in material well-being that science offers are realities. Yet the very fact that they are possibilities has changed the nature of the responsibility which we bear, both as individuals and as a community of men and women banded together in government. In the Greek cities, political democracy and civilization itself appeared possible only on the basis of a slave economy. Technology, born of science, has altered that; it has enabled mankind, as it has forced mankind, to deal with the issues of slavery as a moral issue. Poverty has always been an ugly thing, and in its extremes a desperate one. Today it is an evil, in the sense that it lies within human hands and human hearts to abate it. Science can provide us, for the first time in history, with the means of abating hunger for everyone on earth.

Perhaps nowhere has the impact of science more clearly altered the specific terms of a great political issue than in the effects of scientific development on warfare. This is a can of worms with which I have myself unhappily been engaged for some years. It would not be honest to say—as it would be folly not to hope—that the very terror of modern weapons would in itself put an end to war; it would not even be honest to say that because of this terror the abolition of war and the maintenance of peace have become the one absolute, final objective of all political decisions. There are other things in

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which man has a choice; it has extended man's freedom to make significant decisions. Is there anything in the methods of science itself, or in the spirit of science, which can help in the making of these decisions? To what extent is there a play on the word *science* which can mislead us and take us up false roads when we speak of this science of human relationships? Is there anything we can learn from the relevance of science to politics?

If we are to answer these questions and answer them honestly, we must recognize important and basic differences between problems of science and problems of action as they arise in personal or in political life. If we fail to recognize these differences, we shall be seeking magic solutions and not real ones. We shall delude ourselves into laying aside responsibility, which it is an essential part of man's life to bear.

In most scientific study, questions of good and evil or right and wrong play at most a minor and secondary part. For practical decisions of policy, they are basic. Without them political action would be meaningless. Practical decisions and, above all, political decisions can never quite be freed from the conflicting claims of special interest. These too are part of the meaning of a decision and of a course of action, and they must be an essential part of the force of its implementation.

Political decisions are unique acts. In politics there is little that can correspond to the scientist's repetition of an experiment. An experiment that fails in its purpose may be as good or better than one that succeeds, because it may well be more instructive. A political decision cannot be taken twice. All

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man's life—his freedom, his decency, his sense of right and wrong—that cannot so lightly be subjected to a single end. But what we need to remember is that war today has become, and is increasingly becoming, something very different from what it was a century ago or a millennium ago. We need to recognize the new situation as new; we need to come to it with something of the same spirit as the scientist's when he has conducted an experiment and finds that the results are totally other than those that he had anticipated.

Four months before Hiroshima, in the last days of his life, President Roosevelt's thoughts turned to these questions. In the last words that he wrote, in words he did not live to speak, the President looked to the future, to the atomic age. He looked to the past, to the days of the founding of the Republic. He wrote:

"Thomas Jefferson, himself a distinguished scientist, once spoke of the 'brotherly spirit of science, which unites into one family all its votaries of whatever grade, and however widely dispersed throughout the different quarters of the globe.'

"Today science has brought all the different quarters of the globe so close together that it is impossible to isolate them one from another.

"Today we are faced with the pre-eminent fact that, if civilization is to survive, we must cultivate the science of human relationships—the ability of all peoples, of all kinds, to live together and work together, in the same world, at peace."

Science has greatly extended the range of questions in

which man has a choice; it has extended man's freedom to make significant decisions. Is there anything in the methods of science itself, or in the spirit of science, which can help in the making of these decisions? To what extent is there a play on the word *science* which can mislead us and take us up false roads when we speak of this science of human relationships? Is there anything we can learn from the relevance of science to politics?

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I will quote one characteristic passage which may strike a familiar and homely note for you:

". . . the science of calculation also is indispensible as far as the extraction of the square and cube roots; Algebra as far as the quadratic equation and the use of logarithms are often of value in ordinary cases: but all beyond these is but a luxury; a delicious luxury indeed; but not to be indulged in by one who is to have a profession to follow for his subsistence."

But that is not really the part of Jefferson's letter which I commend to you. Here it is:

"I am among those who think well of the human character generally. I consider man as formed for society, and endowed by nature with those dispositions which fit him for society. I believe also, with Condorcet, as mentioned in your letter, that his mind is perfectible to a degree of which we cannot as yet form any conception. It is impossible for a man who takes a survey of what is already known, not to see what an immensity in every branch of science yet remains to be discovered, and that too of articles to which our faculties seem adequate."

And later, in the same letter, still more explicitly:

". . . and it is still more certain that in the other branches of science, great fields are yet to be explored to which our faculties are equal, and that to an extent of which we cannot fix the limits. I join you therefore in branding as cowardly the idea that the human mind is incapable of further advances. This is precisely the doctrine which the present des-

science and that in turn has provided the great enriching human faith in which scientific discovery and invention have flourished. Jefferson is confident that an increased understanding of the world will lead to progress; he is convinced that the barbarisms of the past cannot stand up against inquiry and understanding and enlightenment; he is confident in man and sure that as men know more they will act more wisely and live better. In our contemporary expressions of hope that catastrophe can be averted and civilization yet be saved, that confidence has lost much of its robustness.

The second point is that for Jefferson there is something in the ways of science that is relevant to political life. Even in religion and politics, he holds that it is probable that things better will be discovered than what was known to our fathers. This conviction that new knowledge is possible, and that not all the answers are known, is of course the stuff of the day-to-day life of the scientist. Science itself does progress; new knowledge is possible; and new knowledge, because it does not destroy or ignore the old, can only increase our understanding. The very idea of the development of science is an example of progress, and of progress which in no true sense can ever be reversed. But this is only part of the story. It is true, as Jefferson knew, that in the large, science has flourished in conditions of human freedom, and that its growth is parallel to the growth of democratic institutions. Today, looking back on more than a century and a half of further history, we can be even more sure of this. We have seen not only the inspiring example of science and democracy flourishing together, but the tragic examples of their found-

could not be applied in the domain of atomic phenomena. There is probably no group of men who take more for granted in their daily work than the scientists. Common sense and all that flows from it are their principal basis for what they do in the laboratory and for what they make of it on paper. But for scientists it is not only honorable to doubt; it is mandatory to do that when there appears to be evidence in support of the doubt. In place of authority in science we have and we need to have only the consensus of informed opinion, only the guide of example. No scientist needs to order his colleagues to use a new technique of experiment or to enter a new field of discovery. If he has done this, it will be an invitation to his fellows to follow.

These, then, are some of the attitudes of mind, these are some of the disciplines of spirit which grow naturally in the scientist's world. They have grown there in part as a result of a humane and liberal tradition in political life and in part as a cause of that. The open mind, the reliance on example and persuasion rather than on authority—these are the heritage of the centuries in which science has altered the face of the earth. Science can help in diverse ways in preserving and extending this heritage. Its very universality speaks across frontiers to make truth manifest in lands otherwise darkened; its material applications create the preconditions —in leisure, in education, in means of communication—for the converse of men with one another. Science provides the material and the intellectual basis for a world in which example and understanding can help all men to improve their lot and fulfill their hopes. Today we need to remember that

ering together. We express the hope that of this tragedy we shall soon have seen the end.

What are these lessons that the spirit of science teaches us for our practical affairs? Basic to them all is that there may be no barriers to freedom of inquiry. Basic to them all is the ideal of openmindedness with regard to new knowledge, new experience and new truth. Science is not based on authority. It owes its acceptance and its universality to an appeal to intelligible, communicable evidence that any interested man can evaluate.

There is no place for dogma in science. The scientist is free to ask any question, to doubt any assertion, to seek for any evidence, to correct any error. Where science has been used in the past to erect a new dogmatism, that dogmatism has found itself incompatible with the progress of science; and in the end, the dogma has yielded, or science and freedom have perished together.

Our own political life is predicated on openness. We do not believe any group of men adequate enough or wise enough to operate without scrutiny or without criticism. We know that the only way to avoid error is to detect it, that the only way to detect it is to be free to inquire. We know that the wages of secrecy are corruption. We know that in secrecy error, undetected, will flourish and subvert.

Let me be clear. Science is not skepticism. It is not the practice of science to look for things to doubt. It was not by a deliberate attempt of skepticism that physicists were led to doubt the absolute nature of simultaneity, or to recognize that the ideas of strict causality embodied in classical physics

could not be applied in the domain of atomic phenomena. There is probably no group of men who take more for granted in their daily work than the scientists. Common sense and all that flows from it are their principal basis for what they do in the laboratory and for what they make of it on paper. But for scientists it is not only honorable to doubt; it is mandatory to do that when there appears to be evidence in support of the doubt. In place of authority in science we have and we need to have only the consensus of informed opinion, only the guide of example. No scientist needs to order his colleagues to use a new technique of experiment or to enter a new field of discovery. If he has done this, it will be an invitation to his fellows to follow.

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our country, founded on these practices and grown strong by their exercise, owes its strength to them. In this time of crisis, we need to cherish that strength.

And this brings me to my second wish for you. I wish you not only the joy of great discovery; I wish for you a world of confidence in man and man's humanity, a world of confidence in reason, so that as you work you may be inspired by the hope that what you find will make men freer and better—*in which, working as specialists in what may be recondite* parts of the intellectual life of the time, you are nevertheless contributing in a direct and basic way to the welfare of mankind.

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VII

The Scientist in Society

THERE IS something inherently comforting about a panel of experts. One knows that the partial and inadequate and slanted and personal views that he expresses will be corrected by the less partial, less personal views of everyone else on the panel; it is not unlike the experience of the professor who always is glad that he has to meet his class again because he can correct the mistakes that he made the last time. It is with such tentativeness that I am going to talk to you.

This is a vast terrain—one full of strange precipices,

the thinking caps of men and which derived from experience in science are really not contemporary ideas but go back a century or two centuries or more.

The second, of course, is not to try to give to scientific life an autonomy of society. It is possible, manifestly, for society so to arrange things that there is no science. The Nazis made a good start in that direction; maybe the Communists will achieve it; and there is not one of us free of the worry that this flourishing tree may someday not be alive any more.

But nonetheless we *have* changed the face of the earth; any beginning of a talk about science and society must take that as a fact.

There is another theme. This is a time that tends to believe in progress. Our ways of thought, our ways of arranging our personal lives, our political forms, point to the future, point not merely to change, to decay, to alteration, but point with a hopeful note of improvement that our progress is inevitable. In the acquisition of knowledge, in the very notion of a cumulative discipline, tomorrow in a certain sense comprises today and yesterday. How much this built-in sense of progress in man's life—which is, I think, not a religious notion, not a Christian notion—how much this derives from the effects of science on philosophical and political thought I would leave to historians of ideas. It is probably not wholly trivial.

A third theme is that science in a certain sense is universal. It is not universal in the sense that all men participate in it. It is universal in the sense that all men can participate in it. It is nonnational, nonlocal and, although one would not say noncultural, singularly independent of the form of govern-

the thinking caps of men and which derived from experience in science are really not contemporary ideas but go back a century or two centuries or more.

The second, of course, is not to try to give to scientific life an autonomy of society. It is possible, manifestly, for society so to arrange things that there is no science. The Nazis made a good start in that direction; maybe the Communists will achieve it; and there is not one of us free of the worry that this flourishing tree may someday not be alive any more.

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ment, the immediate tradition, or the affective life of a people. It has to do with *humanitas.* This universality is not a trivial thing at a time when forms of unity, large forms of unity in the world, appear to be for other reasons rather necessary. This has been very much in all our minds in the years since the last war. I remember that on one occasion when I was in this hall, at the Bicentennial of the University, we were talking about the universality of science; and at that very moment the Soviet delegate to the United Nations Atomic Energy Commission was imploring his government for permission to accept the scientific and technical report of the subcommittee of this commission. This, I think, is the last time—the last time I remember—that the Soviet government has said *yes* to anything, has said *yes* to an agreement of fact. I know how bitterly disappointing the experiences of these years have been as to universality of science, but we all know that this is bad politics but not bad science. We all know that there is no such thing as German physics or Soviet genetics or American astronomy. These fields can open themselves to all reasonable men willing to take the trouble to inquire.

There is also what may first seem like the opposite of universality; I hope you will bear that in mind when I talk of science as a great and beautiful word. There is a unity to it; but there is also an even more striking and immense diversity. Both of your speakers this morning are physicists, and I think we are very different from our brothers the chemists and our brothers the mathematicians. In our values, in our style, we are different. Physics is perhaps the branch of science which

has been most concerned to keep itself one. The Physical Society splits off divisions from time to time but is reluctant to do so; and the divisions largely have to do with semi-applied science. Physics has a history of close association with mathematics, with astronomy, with epistemology and cosmology too. And yet we do not know very much about the rest of the scientists. I know that it is a very happy occasion at the Institute when some piece of work turns up which is of interest to both the mathematicians and the physicists. It is a very rare occasion and we tend to ring bells when a small bit of cement can be found between their interests. I would stress especially that there is no systematic unity of techniques, of appreciation, of values, of style between the many things that we call science. There is a lot of difference between the nuclear physicist and the agricultural scientist exploring the possibility of improving crops in some poor island in the Caribbean. They are scientists, and they understand each other, and we hope love each other. But they are not very much alike.

There are perhaps two or three other general things. One I believe may be of more importance to some of the other panels than to this. This is one of the by-products of the great flowering of science that dates back to the time when science did have an effect on culture and on ideas. We have been impressed, and I must say I never stop being impressed, by the great sweep of general order in which particulars are recognized as united. You know the examples: electricity and light, the quantum theory and the theory of valence, places where things that appeared to be separate, and each having

panel on the role of the artist, or the panel on the role of the philosopher. To put it with great brutality, the point is that the scientist is not in society today, any more than is the artist or the philosopher.

Of course, he does get paid, he does get patronized and even, for odd reasons that he sometimes does not understand, respected. But he is not in society, in the sense that the ideas he has, the work he is doing, stop really rather short with the limits of his profession. They are not part of the intellectual and cultural life of the times. I am over and over again appalled by how ignorant, how incredibly ignorant of the most rudimentary things about my subject are my fellows the historians, my acquaintances the statesmen, my friends the men of affairs. They have no notion of what cooks in physics; I think that they have very little notion of what cooks in any other science. And I know that only by good luck and some hard work do I have even a rudimentary notion of what cooks in other parts of the house called science than the one that I live in. I read the *Physical Review* and work very hard to catch up with it every two weeks; and I think maybe I have some notion of what is going on in some parts of physics; but by and large we know little about one another, and the world outside knows nothing about us. I think this may vary a little from place to place. Perhaps it is tradition in Britain, where there is a sort of deliberate tendency, a national tendency, to refuse to let things become obscure and recondite, that there is a little more effort to see that civilized men have a notion of what the mathematicians and astronomers and physicists are doing—not merely to know the by-products of

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their works, the practical products, but what they are thinking.

This is in very sharp contrast, this startling general ignorance of scientific ideas and discoveries at the edge of the technical disciplines, in very sharp contrast to the state of affairs two or three centuries ago; and some of the reasons for this are manifest. But I believe that the science of today is subtler, richer, more relevant to man's life and more useful to man's dignity than the science which had such a great effect on the age of the enlightenment, had such a great effect, among other things, on the forms and patterns, traditions and hopes—reflected in our Constitution—of human society. Science is not retrograde; and there is no doubt that the quantum mechanics represents a more interesting, more instructive, richer analogy of human life than Newtonian mechanics could conceivably be. There is no doubt that even the theory of relativity, which has been so much vulgarized and so little understood, that even the theory of relativity is a matter which would be of real interest to people at large. There is no doubt that the findings of biology and astronomy and chemistry are discoveries that would enrich our whole culture if they were understood. And what is perhaps more troublesome, there is a gulf between the life of the scientist and the life of a man who isn't actively a scientist, dangerously deep. The experience of science—to stub your toe hard and then notice that it was really a rock on which you stubbed it—this experience is something that is hard to communicate by popularization, by education, or by talk. It is almost as hard to tell a man what it is like to find out something new

about the world as it is to describe a mystical experience to a chap who has never had any hint of such an experience.

The enlightenment was a peculiar time; it was hopeful, and superficial, and humane; and how much of the ideas of the enlightenment derived from an appreciation of science, it is perhaps not right for anyone but a careful historian to say. But we know that the same men who wrote about politics and philosophy—not very good philosophy, and not too good politics—also wrote about natural science, about physics, and astronomy, and mathematics. We know that on two very different planes Franklin and Jefferson managed to span the whole way from a living, and in some cases even practicing, interest in science to the world of affairs. And we know how full their writings are of the illumination which one sheds on the other.

Science in those days was connected with the practical arts; it was very close to common sense. Yet always there is in science little more than the infinitely diligent and patient and unremitting application of the practical arts and common sense. By now it has come to be a long chain. The mere process of carrying a boy through the elementary steps of this chain consumes so much of his life and is such an exhausting operation, to the teacher and student alike, that the simple means of communication and understanding, which sufficed in the seventeenth and eighteenth centuries, are clearly not good enough.

This is a problem that has had the thought of many wise people; I do not pretend to be talking of anything new or strange. I suppose the notion of having laboratory courses

have, in so far as we have at all, a philosophy that is quite anachronistic and, I am convinced, quite inadequate to our times. I think that whatever may have been thought of Cartesian and Newtonian reforms in the intellectual life of Europe, the time when these were what the doctor ordered—all that the doctor ordered—is long past. Far more subtle recognition of the nature of man's knowledge and of his relations to the universe is certainly long overdue, if we are to do justice to the wisdom which our tradition has in it and to the brilliant and ever-changing flower of discovery which is modern science.

Research is action; and the question I want to leave in a very raw and uncomfortable form with you is how to communicate this sense of action to our fellow men who are not destined to devote their lives to the professional pursuit of new knowledge.

VIII

Prospects in the Arts and Sciences

THE WORDS "prospects in the arts and sciences" mean two quite different things to me. One is prophecy: What will the scientists discover and the painters paint, what new forms will alter music, what parts of experience will newly yield to objective description? The other meaning is that of a view: What do we see when we look at the world today and compare it with the past? I am not a prophet; and I cannot very well speak to the first subject, though in many ways I should like to. I shall try to speak to the second, because there are some features of this view which seem to me so remarkable,

of culture, in matters precisely of the arts and sciences, a certain macrohistorical pattern, a grand system of laws which determines the course of civilization and gives a kind of inevitable quality to the unfolding of the future. They would, for instance, see the radical, formal experimentation which characterized the music of the last half-century as an inevitable consequence of the immense flowering and enrichment of natural science; they would see a necessary order in the fact that innovation in music precedes that in painting and that in turn in poetry, and point to this sequence in older cultures. They would attribute the formal experimentation of the arts to the dissolution, in an industrial and technical society, of authority—of secular, political authority, and of the catholic authority of the church. They are thus armed to predict the future. But this, I fear, is not my dish.

If a prospect is not a prophecy, it is a view. What does the world of the arts and sciences look like? There are two ways of looking at it: One is the view of the traveler, going by horse or foot, from village to village to town, staying in each to talk with those who live there and to gather something of the quality of its life. This is the intimate view, partial, somewhat accidental, limited by the limited life and strength and curiosity of the traveler, but intimate and human, in a human compass. The other is the vast view, showing the earth with its fields and towns and valleys as they appear to a camera carried in a high-altitude rocket. In one sense this prospect will be more complete; one will see all branches of knowledge, one will see all the arts, one will see them as part of the vastness and complication of the whole of human life

so new and so arresting, that it may be worth turning our eyes to them; it may even help us to create and shape the future better, though we cannot foretell it.

In the arts and in the sciences, it would be good to be a prophet. It would be a delight to know the future. I had thought for a while of my own field of physics and of those nearest to it in the natural sciences. It would not be too hard to outline the questions which natural scientists today are asking themselves and trying to answer. What, we ask in physics, is matter, what is it made of, how does it behave when it is more and more violently atomized, when we try to pound out of the stuff around us the ingredients which only violence creates and makes manifest? What, the chemists ask, are those special features of nucleic acids and proteins which make life possible and give it its characteristic endurance and mutability? What subtle chemistry, what arrangements, what reactions and controls make the cells of living organisms differentiate so that they may perform functions as oddly diverse as transmitting information throughout our nervous systems or covering our heads with hair? What happens in the brain to make a record of the past, to hide it from consciousness, to make it accessible to recall? What are the physical features which make consciousness possible?

All history teaches us that these questions that we think the pressing ones will be transmuted before they are answered, that they will be replaced by others, and that the very process of discovery will shatter the concepts that we today use to describe our puzzlement.

It is true that there are some who profess to see in matters

starting anywhere, ending anywhere, and sometimes appearing almost by design to disrupt the quiet of the village. This view gives us no sense of order or of unity. To find these we must visit the villages, the quiet, busy places, the laboratories and studies and studios. We must see the paths that are barely discernible; we must understand the superhighways and their dangers.

In the natural sciences these are and have been and are likely to continue to be heroic days. Discovery follows discovery, each both raising and answering questions, each ending a long search, and each providing the new instruments for a new search. There are radical ways of thinking unfamiliar to common sense and connected with it by decades or centuries of increasingly specialized and unfamiliar experience. There are lessons of how limited, for all its variety, the common experience of man has been with regard to natural phenomena, and hints and analogies as to how limited may be his experience with man. Every new finding is a part of the instrument kit of the sciences for further investigation and for penetrating into new fields. Discoveries of knowledge fructify technology and the practical arts, and these in turn pay back refined techniques, new possibilities of observation and experiment.

In any science there is harmony between practitioners. A man may work as an individual, learning of what his colleagues do through reading or conversation; he may be working as a member of a group on problems whose technical equipment is too massive for individual effort. But whether he is a part of a team or solitary in his own study, he, as a

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professional, is a member of a community. His colleagues in his own branch of science will be grateful to him for the inventive or creative thoughts he has, will welcome his criticism. His world and work will be objectively communicable; and he will be quite sure that if there is error in it, that error will not long be undetected. In his own line of work he lives in a community where common understanding combines with common purpose and interest to bind men together both in freedom and in co-operation.

This experience will make him acutely aware of how limited, how inadequate, how precious is this condition of his life; for in his relations with a wider society, there will be neither the sense of community nor of objective understanding. He will sometimes find, in returning to practical undertakings, some sense of community with men who are not expert in his science, with other scientists whose work is remote from his, and with men of action and men of art. The frontiers of science are separated now by long years of study, by specialized vocabularies, arts, techniques, and knowledge from the common heritage even of a most civilized society; and anyone working at the frontier of such science is in that sense a very long way from home, a long way too from the practical arts that were its matrix and origin, as indeed they were of what we today call art.

The specialization of science is an inevitable accompaniment of progress; yet it is full of dangers, and it is cruelly wasteful, since so much that is beautiful and enlightening is cut off from most of the world. Thus it is proper to the role of the scientist that he not merely find new truth and com-

municate it to his fellows, but that he teach, that he try to bring the most honest and intelligible account of new knowledge to all who will try to learn. This is one reason—it is the decisive organic reason—why scientists belong in universities. It is one reason why the patronage of science by and through universities is its most proper form; for it is here, in teaching, in the association of scholars and in the friendships of teachers and taught, of men who by profession must themselves be both teachers and taught, that the narrowness of scientific life can best be moderated, and that the analogies, insights, and harmonies of scientific discovery can find their way into the wider life of man.

In the situation of the artist today there are both analogies to and differences from that of the scientist; but it is the differences which are the most striking and which raise the problems that touch most on the evil of our day. For the artist it is not enough that he communicate with others who are expert in his own art. Their fellowship, their understanding, and their appreciation may encourage him; but that is not the end of his work, nor its nature. The artist depends on a common sensibility and culture, on a common meaning of symbols, on a community of experience and common ways of describing and interpreting it. He need not write for everyone or paint or play for everyone. But his audience must be man; it must be man, and not a specialized set of experts among his fellows. Today that is very difficult. Often the artist has an aching sense of great loneliness, for the community to which he addresses himself is largely not there; the traditions and the culture, the symbols and the history,

not because it has never been there before, but because it has changed in quality. One thing that is new is the prevalence of newness, the changing scale and scope of change itself, so that the world alters as we walk in it, so that the years of man's life measure not some small growth or rearrangement or moderation of what he learned in childhood, but a great upheaval. What is new is that in one generation our knowledge of the natural world engulfs, upsets, and complements all knowledge of the natural world before. The techniques, among which and by which we live, multiply and ramify, so that the whole world is bound together by communication, blocked here and there by the immense synapses of political tyranny. The global quality of the world is new: our knowledge of and sympathy with remote and diverse peoples, our involvement with them in practical terms, and our commitment to them in terms of brotherhood. What is new in the world is the massive character of the dissolution and corruption of authority, in belief, in ritual, and in temporal order. Yet this is the world that we have come to live in. The very difficulties which it presents derive from growth in understanding, in skill, in power. To assail the changes that have unmoored us from the past is futile, and in a deep sense, I think, it is wicked. We need to recognize the change and learn what resources we have.

Again I will turn to the schools and, as their end and as their center, the universities. For the problem of the scientist is in this respect not different from that of the artist or of the historian. He needs to be a part of the community, and the community can only with loss and peril be without him. Thus

it is with a sense of interest and hope that we see a growing recognition that the creative artist is a proper charge on the university, and the university a proper home for him; that a composer or a poet or a playwright or painter needs the toleration, understanding, the rather local and parochial patronage that a university can give; and that this will protect him from the tyranny of man's communication and professional promotion. For here there is an honest chance that what the artist has of insight and of beauty will take root in the community, and that some intimacy and some human bonds can mark his relations with his patrons. For a university rightly and inherently is a place where the individual man can form new syntheses, where the accidents of friendship and association can open a man's eyes to a part of science or art which he had not known before, where parts of human life, remote and perhaps superficially incompatible, can find in men their harmony and their synthesis.

These, then, in rough and far too general words, are some of the things we see as we walk through the villages of the arts and of the sciences and notice how thin are the paths that lead from one to another, and how little in terms of human understanding and pleasure the work of the villages comes to be shared outside.

The superhighways do not help. They are the mass media—from the loud-speakers in the deserts of Asia Minor and the cities of Communist China to the organized professional theater of Broadway. They are the purveyors of art and science and culture for the millions upon millions—the promoters who represent the arts and sciences to humanity and

who represent humanity to the arts and sciences; they are the means by which we are reminded of the famine in remote places or of war or trouble or change; they are the means by which this great earth and its peoples have become one to one another, the means by which the news of discovery or honor and the stories and songs of today travel and resound throughout the world. But they are also the means by which the true human community, the man knowing man, the neighbor understanding neighbor, the schoolboy learning a poem, the women dancing, the individual curiosity, the individual sense of beauty are being blown dry and issueless, the means by which the passivity of the disengaged spectator presents to the man of art and science the bleak face of unhumanity.

For the truth is that this is indeed, inevitably and increasingly, an open and, inevitably and increasingly, an eclectic world. We know too much for one man to know much, we live too variously to live as one. Our histories and traditions—the very means of interpreting life—are both bonds and barriers among us. Our knowledge separates as well as it unites; our orders disintegrate as well as bind; our art brings us together and sets us apart. The artist's loneliness, the scholar despairing because no one will any longer trouble to learn what he can teach, the narrowness of the scientist—these are unnatural insignia in this great time of change.

For what is asked of us is not easy. The openness of this world derives its character from the irreversibility of learning; what is once learned is part of human life. We cannot close our minds to discovery; we cannot stop our ears so that the voices of far-off and strange people can no longer reach

them. The great cultures of the East cannot be walled off from ours by impassable seas and defects of understanding based on ignorance and unfamiliarity. Neither our integrity as men of learning nor our humanity allows that. In this open world, what is there, any man may try to learn.

This is no new problem. There has always been more to know than one man could know; there have always been modes of feeling that could not move the same heart; there have always been deeply held beliefs that could not be composed into a synthetic union. Yet never before today have the diversity, the complexity, the richness so clearly defied hierarchical order and simplification; never before have we had to understand the complementary, mutually not compatible ways of life and recognize choice between them as the only course of freedom. Never before today has the integrity of the intimate, the detailed, the true art, the integrity of craftsmanship and the preservation of the familiar, of the humorous and the beautiful stood in more massive contrast to the vastness of life, the greatness of the globe, the otherness of people, the otherness of ways, and the all-encompassing dark.

This is a world in which each of us, knowing his limitations, knowing the evils of superficiality and the terrors of fatigue, will have to cling to what is close to him, to what he knows, to what he can do, to his friends and his tradition and his love, lest he be dissolved in a universal confusion and know nothing and love nothing. It is at the same time a world in which none of us can find hieratic prescription or general sanction for any ignorance, any insensitivity, any indifference. When a friend tells us of a new discovery we may not

understand, we may not be able to listen without jeopardizing the work that is ours and closer to us; but we cannot find in a book or canon—and we should not seek—grounds for hallowing our ignorance. If a man tells us that he sees differently than we, or that he finds beautiful what we find ugly, we may have to leave the room, from fatigue or trouble; but that is our weakness and our default. If we must live with a perpetual sense that the world and the men in it are greater than we and too much for us, let it be the measure of our virtue that we know this and seek no comfort. Above all, let us not proclaim that the limits of our powers correspond to some special wisdom in our choice of life, of learning, or of beauty.

This balance, this perpetual, precarious, impossible balance between the infinitely open and the intimate, this time—our twentieth century—has been long in coming; but it has come. It is, I think, for us and our children, our only way.

This is for all men. For the artist and for the scientist there is a special problem and a special hope, for in their extraordinarily different ways, in their lives that have increasingly divergent character, there is still a sensed bond, a sensed analogy. Both the man of science and the man of art live always at the edge of mystery, surrounded by it; both always, as the measure of their creation, have had to do with the harmonization of what is new with what is familiar, with the balance between novelty and synthesis, with the struggle to make partial order in total chaos. They can, in their work and in their lives, help themselves, help one another, and help all men. They can make the paths that connect the vil-

lages of arts and sciences with each other and with the world at large the multiple, varied, precious bonds of a true and world-wide community.

This cannot be an easy life. We shall have a rugged time of it to keep our minds open and to keep them deep, to keep our sense of beauty and our ability to make it, and our occasional ability to see it in places remote and strange and unfamiliar; we shall have a rugged time of it, all of us, in keeping these gardens in our villages, in keeping open the manifold, intricate, casual paths, to keep these flourishing in a great, open, windy world; but this, as I see it, is the condition of man; and in this condition we can help, because we can love, one another.

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